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RADIOLOGICAL SURVEY OF MAJOR CALIFORNIA NUCLEAR PORTS - APRIL 1967

by

D. F. Cahill
D. C. McCurry
W. D. Breakfield

Southeastern Radiological Health Laboratory
P. O. Box 61
Montgomery, Alabama 36101

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
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I. Introduction

The nuclear port surveillance program of the Southeastern Radiological Health Laboratory conducted in conjunction with the Naval Ship Systems Command, U. S. Navy, which included prior surveys at Pearl Harbor, Hawaii; Groton, Connecticut; and Charleston, South Carolina, was extended to the major nuclear ports on the west coast of the United States at San Diego and the Mare Island Naval Shipyard. These ports, which are located in or proximal to the metropolitan areas of San Diego and San Francisco, California, contain berthing, maintenance and/or construction facilities for nuclear powered submarines.

Radiological surveys were conducted at San Diego Bay and its environs from April 3-7, and at the Mare Island Naval Shipyard and environs from April 10-13, 1967. The objectives of the surveys were the location, identification, and quantification of radionuclides, and the assessment of the possible public health implications of nuclear vessel operation in these areas.

II. Equipment

In these surveys, as in the past surveys, the principal investigative instrument was an underwater gamma scintillation detector. This device provided prompt in-the-field data for defining areas of detectable gamma activity. Briefly, the underwater probe consisted of a 4 x 4 NaI (Tl) crystal with associated photomultiplier and preamplifier, sealed within a 7" diameter, 1/2" thick lucite tube. A fitted styrofoam jacket provided shock and thermal protection. This assembly provided detection

of gamma emissions from the harbor bottom with a minimum of photon energy degradation. An improved circuit, derived from Riel's system (1), provided high voltage to a voltage divider and photomultiplier tube in the submerged probe housing via a single cable. The pulses from the photomultiplier tube were transmitted through the same cable to a decoupler on shipboard. The pulses and high voltage were decoupled and the pulse shunted to a transistorized 400-channel Victoreen P I P pulse height analyzer. Data printout was by means of a Teletypewriter and punch tape.

Power was supplied by a 1.5 KW 115V. 60-cycle gasoline generator. Bottom sediment samples were collected with a Standard Birge-Ekman dredge.

III. Sample Collection and Analysis

Probe readings were made by lowering the gamma scintillation detector to the harbor bottom and counting in situ for 10 minutes. A background reading, from an area of harbor bottom previously determined to contain only natural radioactivity, was automatically subtracted.

Three-liter samples of bottom sediment were collected with the Standard Birge-Ekman dredge which is capable of collecting sediment to a depth of 4 inches. Grab samples of shore sand, harbor and tap water, algae, seaweed and fish were also obtained.

Laboratory preparation of bottom sediment included drying at 105°C and grinding to a fine powder prior to gamma pulse height analysis*. Seaweed, algae, and fish samples were dried at 105°,

*Unless otherwise noted, laboratory gamma pulse height analysis consists of counting samples contained in 1-liter Marinelli beakers for 50 minutes over an energy range of 0-3 MeV with a 4 x 4 NaI(Tl) crystal and 400-channel analyzer.

ashed at 450°C and counted in a 4 x 5 NaI(Tl) well crystal for 50 minutes. Shore sand was dried before counting. Water samples to which several ml of 6N HCl has been added to prevent adsorption of activity to the container walls were gamma scanned without further treatment. The alpha and beta activity of representative samples of sediment, water, sand, and biota was also determined.

IV. Probe Calibration

Prior to these surveys re-calibration of the underwater gamma scintillation detector assembly was required due to the use of a new pulse height analyzer and circuitry in the detector system. To improve the value of the instrument as a semi-quantitative tool an effort was made to refine the calibration technique used for the survey at Groton, Connecticut. These improvements were centered on a more realistic simulation of a harbor bottom. Ideally, it would be desirable to submerge the probe and position it over bottom sediments containing cobalt-60 activity, the radionuclide of prime interest in the surveys. However, this approach is impractical because of possible solubilization of the cobalt-60 activity by the overlaying water.

To overcome this problem and provide a reasonable facsimile of actual harbor bottom conditions a plastic pool, 15 feet in diameter and 42 inches in depth was erected. The pool rested on the ground except for a small segment of the pool bottom which covered a slit trench 4-feet wide and 0.5-feet deep, extending radially from the center of the pool past the perimeter. The trench was covered with 0.75-inch thick plywood to support the bottom of the pool.

The trench served as the means by which a circular pan of sediment containing cobalt-60 activity could be positioned under and removed from the probe. When the pool was filled with H_2O and the probe in position, the top of the assembly was under several inches of H_2O and the NaI crystal was submerged to a depth of approximately 3 feet. This provided a large volume for gamma photon absorption and scatter.

Previous tests with point sources of cobalt-60 activity indicated that within reasonable activity ranges the area from which the submerged probe could receive undegraded cobalt-60 photons had a radius of 15 inches. To determine the validity of these earlier measurements of the probe "viewing area" two circular pans were constructed with radii of 15 and 22 inches. Both were filled with sediment containing the same specific activity (100 pCi/gm) of cobalt-60. Analysis of the data from replicate counts of both geometries showed only a slight difference in count rate. It was decided that the 15-inch radius geometry was satisfactory for calibration and meant that the "viewing area" of the probe covered 0.456 M^2.

The cobalt-60 activity had been determined previously to be throughout the top 4 inches of sediment, therefore, the pan was filled to a depth of 4 inches with a known weight of dried sediment. Water was added to form a slurry. A 10-minute background count was made with the sediment slurry in position centered beneath and as close as possible to the submerged probe. The effects of the plywood were ignored. Successive increments

of cobalt-60 activity were added to the slurry, mixed well, and the pan positioned under the probe. Duplicate 10-minute counts were made with the background automatically subtracted.

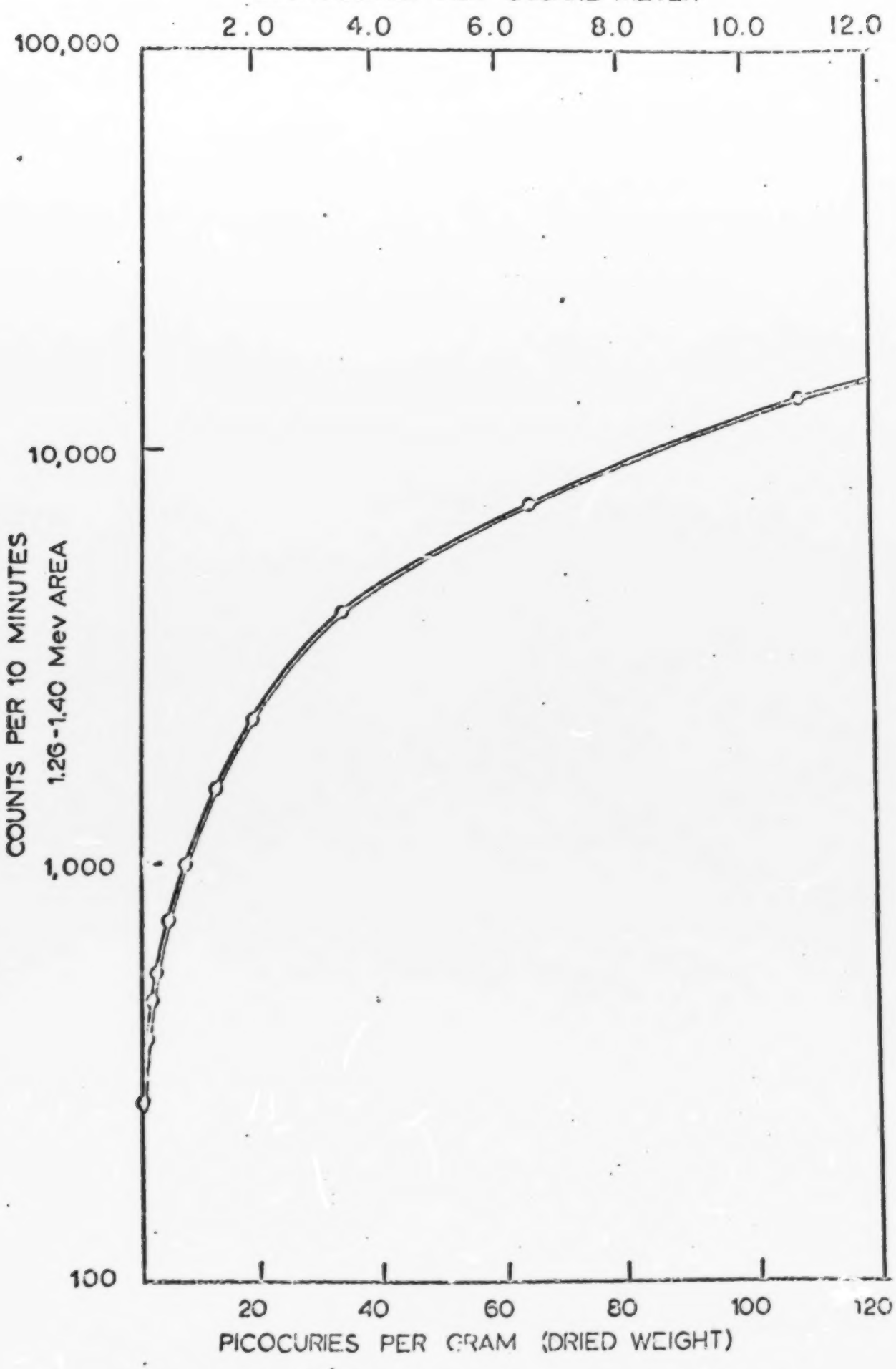
The results of the calibration are presented in Fig. 1 as the sum of the net counts per 10 minutes accumulated in the 15-channel area, 1.26 - 1.40 MeV of cobalt-60 versus $\mu Ci/M^2$ and pCi/gm of cobalt-60 activity in the sediment.

The lower limit of cobalt-60 detectable by the system is approximately 0.1 $\mu Ci/M^2$ or 1.0 pCi/gm dried sediment.

V. Characteristics of San Diego Bay and Environs

A. San Diego Bay is a natural landlocked harbor on the coast of Southern California containing approximately 22 square miles of surface area. The entrance to the bay is formed by Point Loma on the west and North Island on the east. The bay has an axial length of 14.7 statute miles with the main portion of the bay extending in a northwest-southeast direction. The mean width is 1.26 miles varying from .31 miles near the entrance to 2.24 miles at the widest point near the end. The mean tidal range is 4.2 feet and the current at the entrance has an average velocity of 2.4 feet per second and an extreme velocity of 4.55 feet per second[2]. Freshwater inflow for the bay consists of storm runoff and four small rivers which are dry in the summer. This freshwater flow is so small there are no stream guage records showing actual volumes. The average annual rainfall is 10.30 inches, most of

Figure 1. Underwater Probe Calibration Curve



which falls from October through May. Due to the absence of extensive silting from freshwater streams, a minimum of maintenance dredging is required in the bay. The bottom of the bay is characterized by shells and small gravel. Naval facilities are located at a number of points around the harbor with the submarine base, fuel and ammunition piers and floating dry dock at Ballast Point on Point Loma.

Even though commercial fishing is prohibited in the bay, sport fishing is popular and is centered around the municipal fishing pier on Shelter Island. The bay is also a popular area for power boating and sailing. Agriculture is not present along the perimeter of the harbor.

The water supply for the City of San Diego comes from a group of reservoirs in the mountainous area of the county and two aqueducts from the Colorado River.

B. San Diego and Vicinity

The city of San Diego has an estimated population of 670,000 and the metropolitan area has a population exceeding one million. San Diego's major industries are aircraft, shipbuilding and tuna fishing. Naval and marine installations provide employment for a large segment of the total work force.

VI. Results and Discussion

The sediment of San Diego harbor contains natural radioactivity associated with thorium-232 and potassium-40; radioactivity from fallout ruthenium-103 and -106 and zirconium-95 and low levels of cobalt-60 activity. Spectra from the laboratory analysis of sediment and a probe count from the same location are shown in Figures 2 and 3, respectively. Harbor tap water and samples of shore sand, seaweed, and fish contained no radioactivity exclusive of natural activity.

The deposition of cobalt-60 is essentially limited to the area from Ballast Point northward to Shelter Island. The highest activities were detected in the immediate vicinity of the submarine pier, one of the berthing areas for nuclear submarine tenders. Beyond Shelter Island the activity was undetectable with the underwater probe. Figures 4 and 5 show the relative locations of sampling points, while Figures 6 and 7 indicate cobalt-60 distribution in the bay.

VII. Characteristics of Mare Island Strait and Environs

A. Mare Island Strait

Mare Island Strait is located in the northern part of San Pablo Bay 25 miles northeast of San Francisco. The Strait is formed by the City of Vallejo on the east side of the Napa River and Mare Island on the west side. Mare Island Strait is approximately three miles long and is bounded by the Sears Point

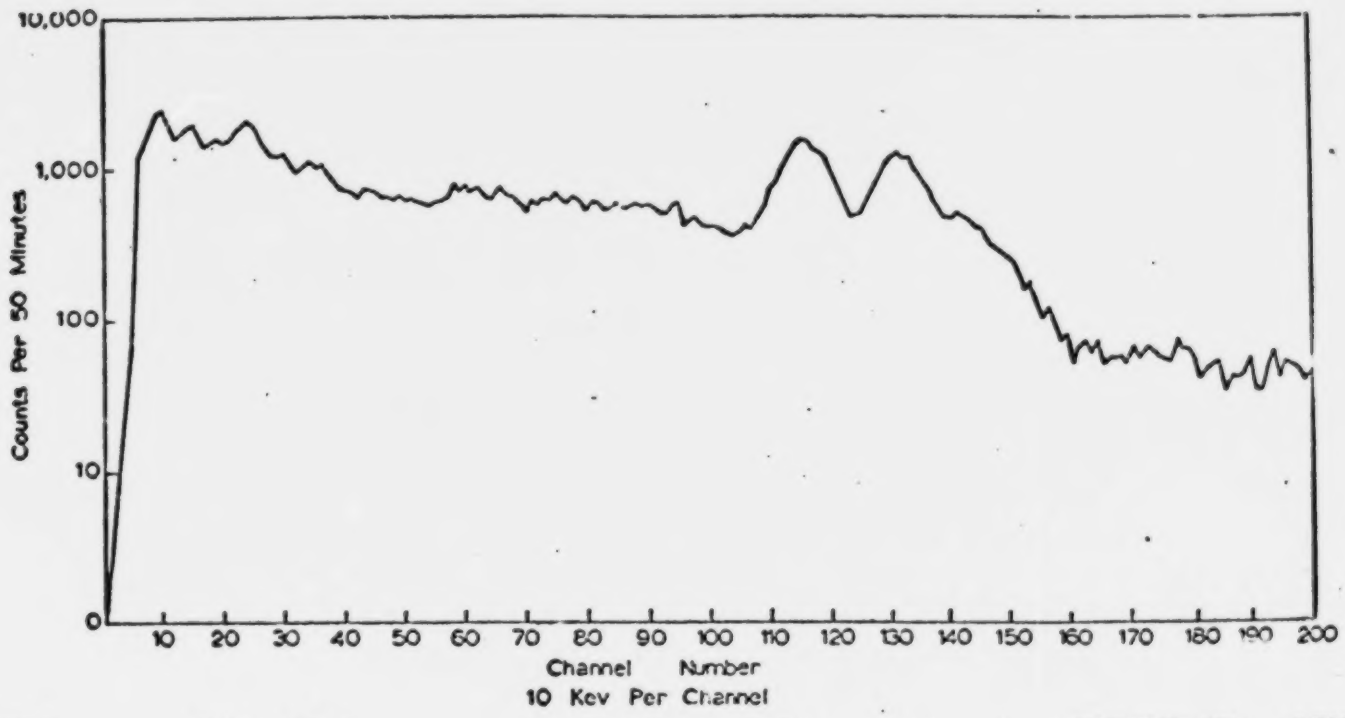


Figure 2. San Diego Harbor Sediment Spectrum - Laboratory Analysis

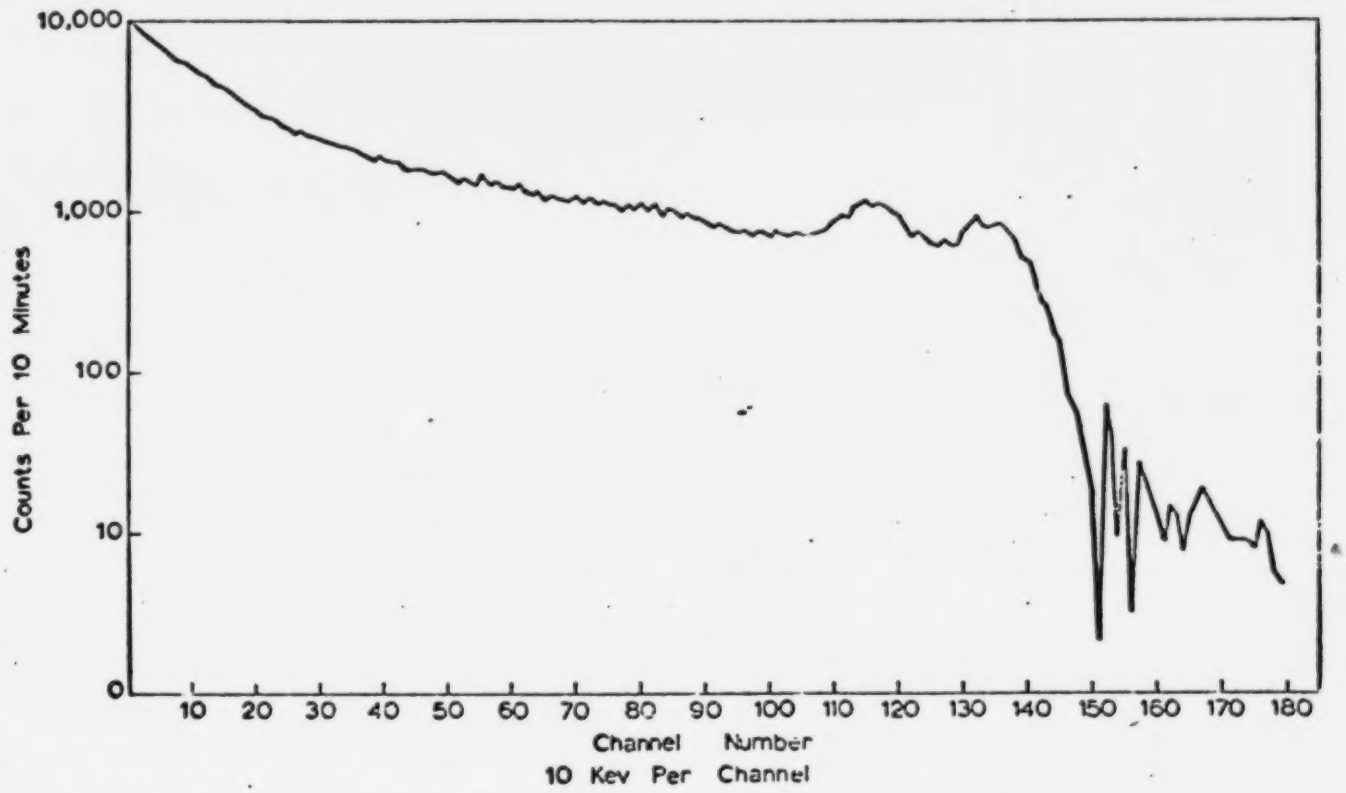


Figure 3. San Diego Harbor Bottom Spectrum - Underwater Probe

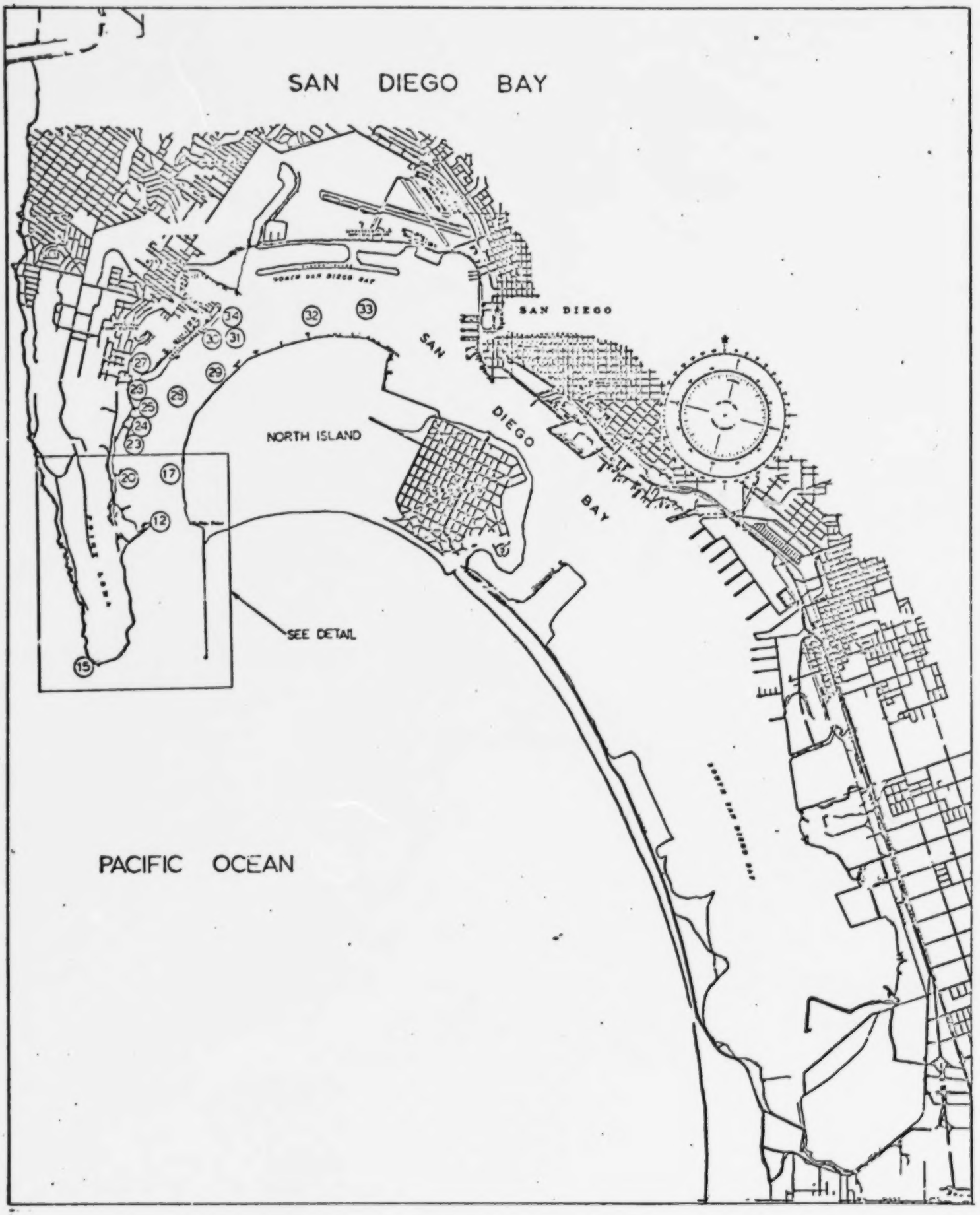


Figure 4. General Location of Sampling Points and Probe Readings in San Diego Bay

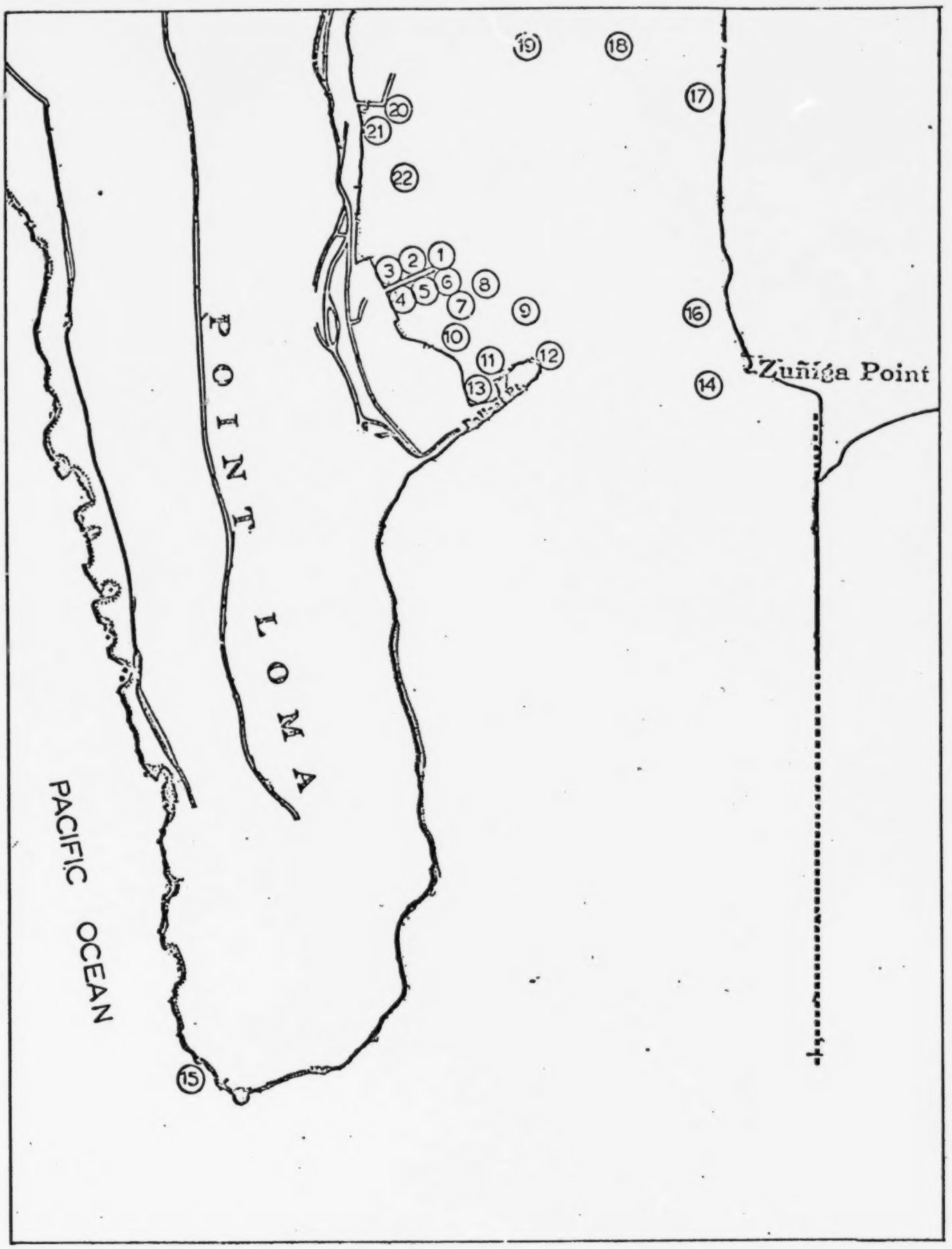


Figure 5. General Location of Sampling Points and Probe Readings Around Submarine Pier

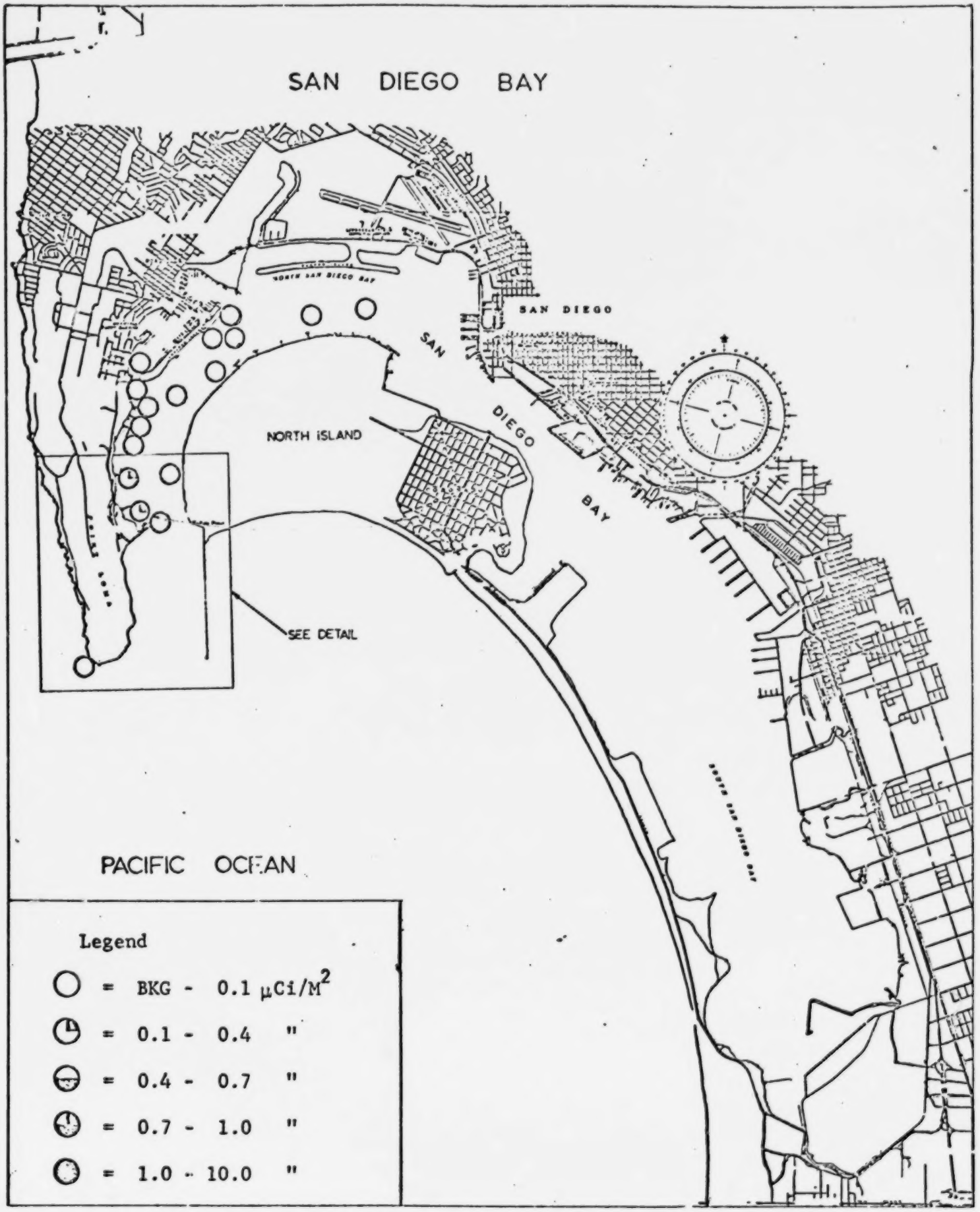


Figure 6. Relative Cobalt-60 Distribution in San Diego Bay

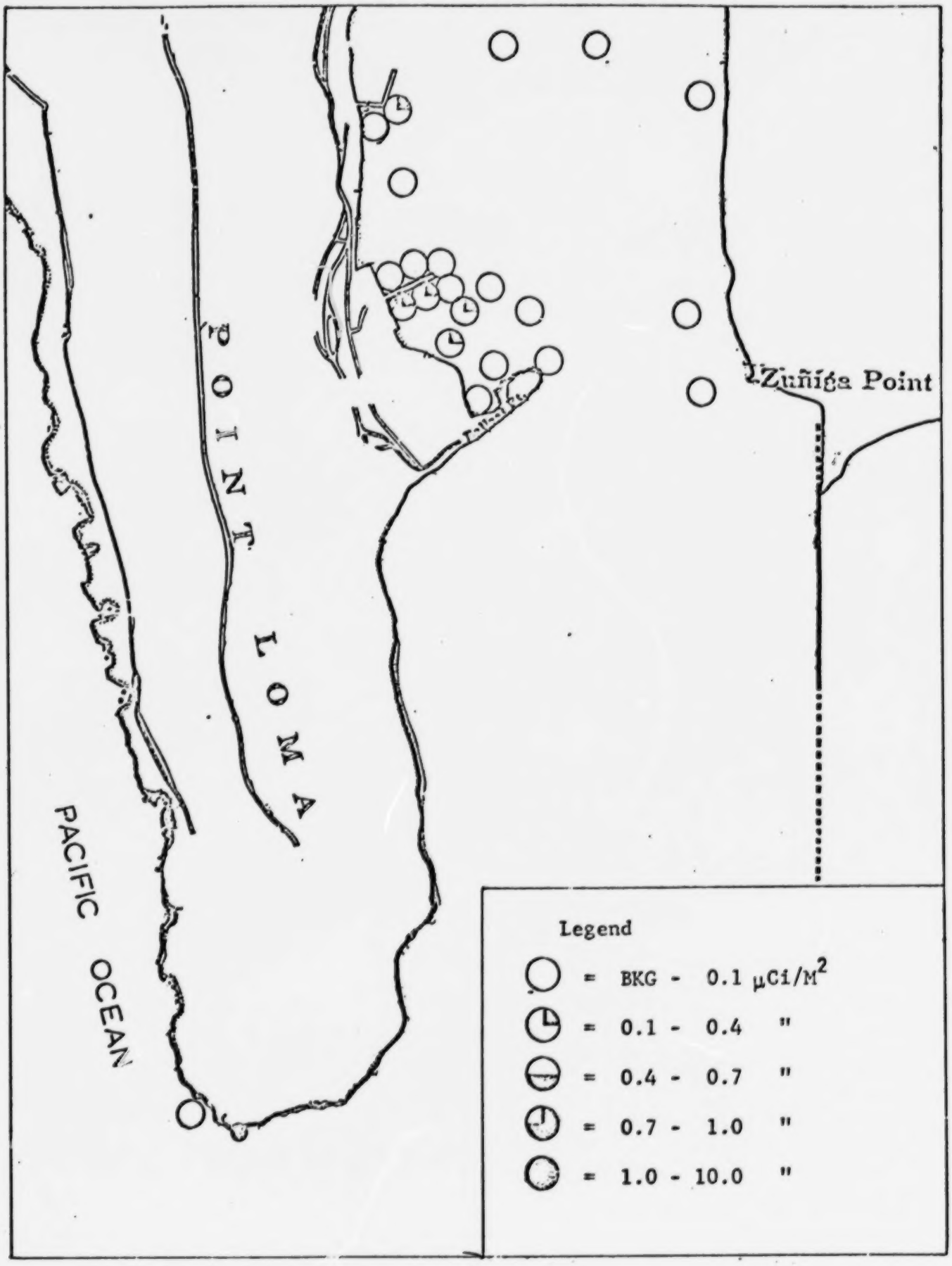


Figure 7. Relative Distribution of Cobalt-60 Around Submarine Base and Pier

Causeway on the north and San Pablo Bay on the south. The width of the Strait varies from approximately one thousand to two thousand feet. The mean tidal range is 4.5 feet and the maximum current velocity is 4.1 feet per second in the Strait(3). The bottom of the Strait is characterized by soft mud and silt. Heavy silting action in the Strait necessitates the removal of approximately two million cubic yards of bottom sediment annually in constant dredging operations(3). Over a significant portion of its length, the Strait is confined between the piers and docks of Mare Island and a sea wall on the opposite shore, precluding bathing and agriculture in the vicinity of the Naval Shipyard.

B. Vallejo and Vicinity

The city of Vallejo has a population of approximately 61,000. Vallejo is in a fertile agricultural section which produces grain, beets, orchard fruits, grapes and livestock. Vallejo's principal industry is the Mare Island Naval Shipyard. Since 1958 when the first nuclear reactor plant attained criticality the shipyard has been involved in the construction, maintenance, and overhaul of nuclear submarines.

Vallejo's water supply comes from Cache Slough

approximately 25 miles northeast of the city with the main pumping station at Maine Prairie Slough. There is no commercial fishing in the Strait but some sport fishing is done.

VIII. Results and Discussion

Cobalt-60 was not detectable at Mare Island Naval Shipyard or its immediate environs by either the underwater probe or laboratory analysis of sediment. Fallout radionuclides were found in the sediments only. These species, i.e., cesium-137, zirconium-95 and ruthenium-103 and -106 were attributed to fallout because of the nearly uniform activity and distribution in the sediment throughout the strait. The usual natural activity was detectable in the water, sediment and environmental samples obtained from this area. Figures 8 and 9 show a laboratory analysis of a bottom sediment and a probe spectrum from the same area. The location of Mare Island Strait in relation to San Francisco Bay is shown in Figure 10. The locations of sampling points and probe readings in Mare Island Strait are shown in Figure 11.

The absence of cobalt-60 activity may be due to the constant dredging of the Strait. However, laboratory analysis of silt samples collected from the dredge discharge point on the west side of Mare Island showed no detectable cobalt-60 activity.

IX. Conclusions

1. The low levels of cobalt-60 activity are restricted to a small area

of San Diego harbor. The slight dispersion of low activities and the absence of activity in environmental samples other than sediment indicate that the operation of nuclear powered submarines in this area under present conditions poses no public health problem.

2. The absence of cobalt-60 activity in the Mare Island Strait and samples of environmental materials indicates there is no public health hazard from the variety of nuclear operations at the shipyard.

Mention of commercial products used in connection with work reported in this article does not constitute an endorsement by the Public Health Service.

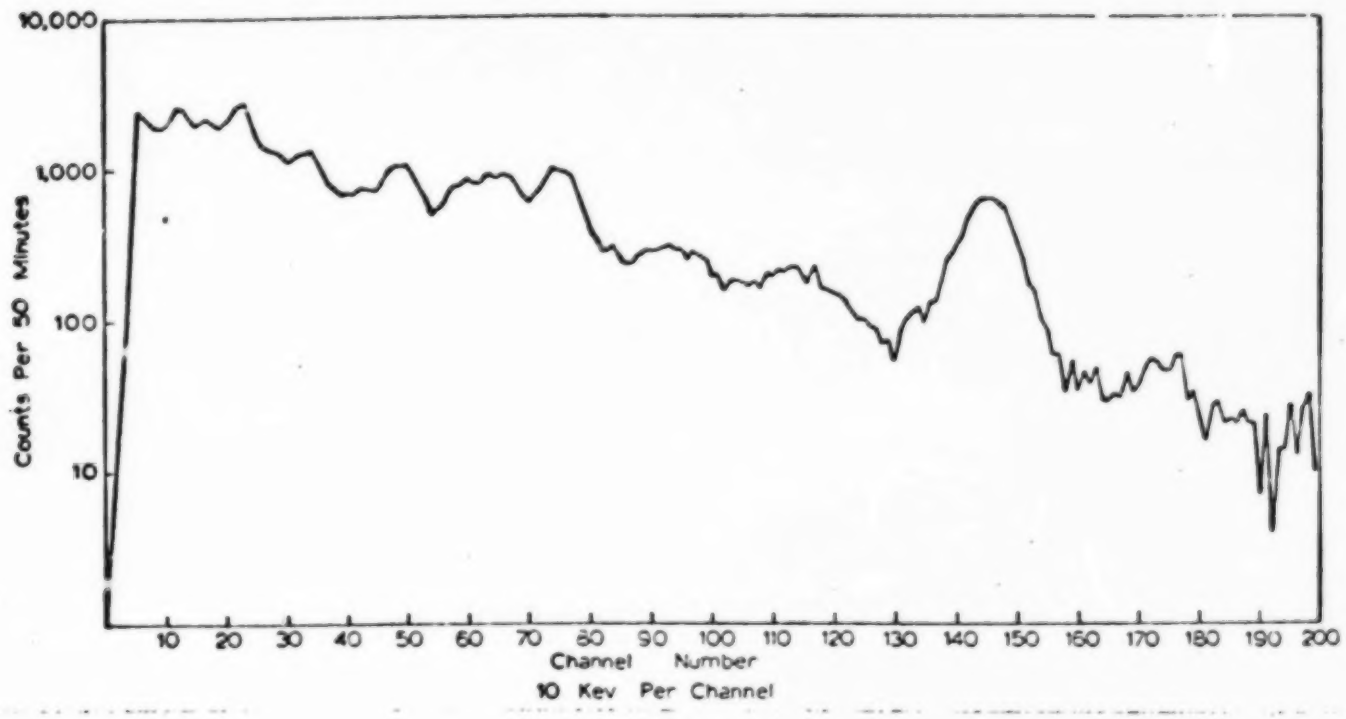


Figure 8. Mare Island Strait Sediment Spectrum - Laboratory Analysis

Figure 9. Mare Island Strait Bottom Spectrum - Underwater Probe

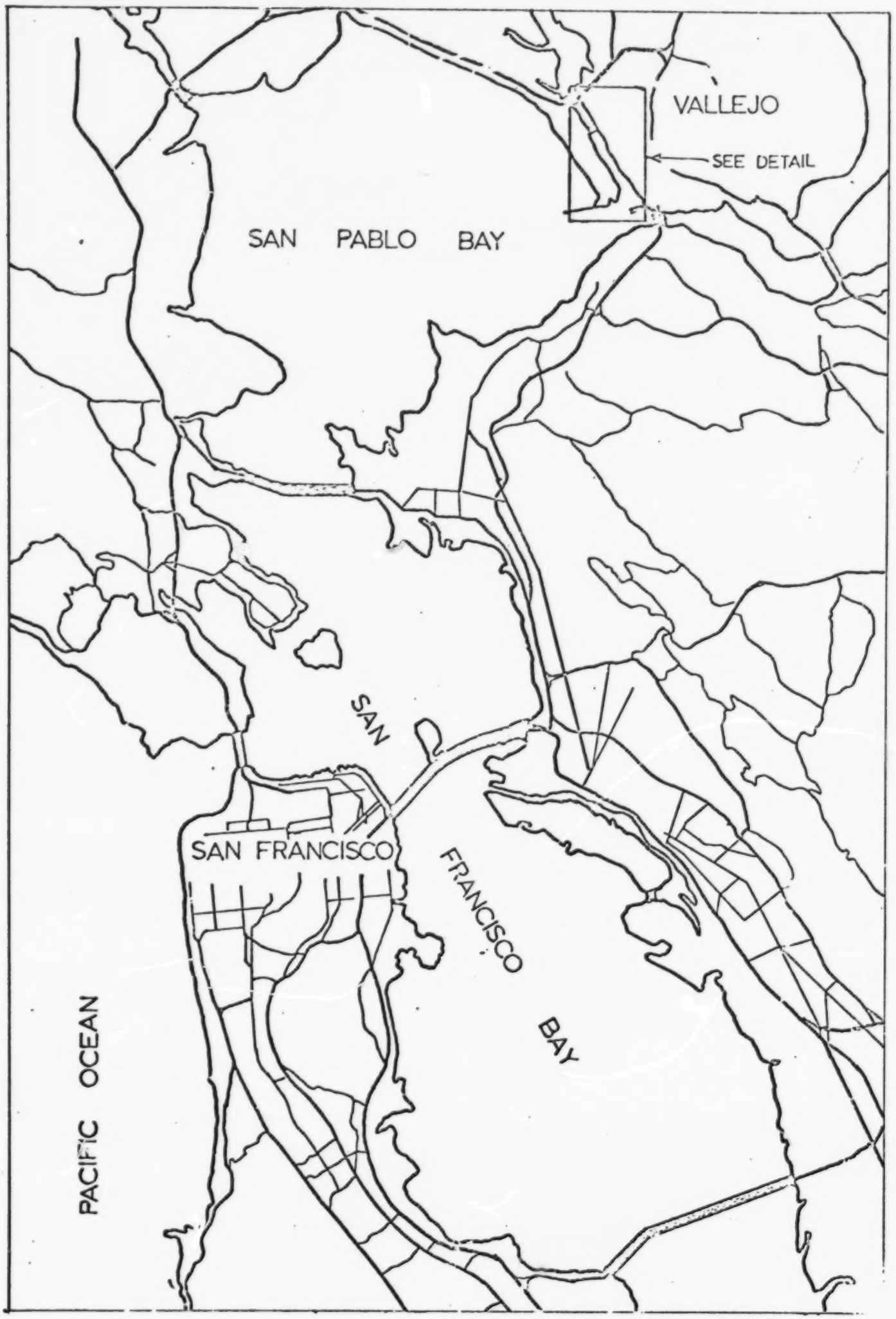


Figure 10. San Francisco Bay Including Vallejo and Mare Island Strait

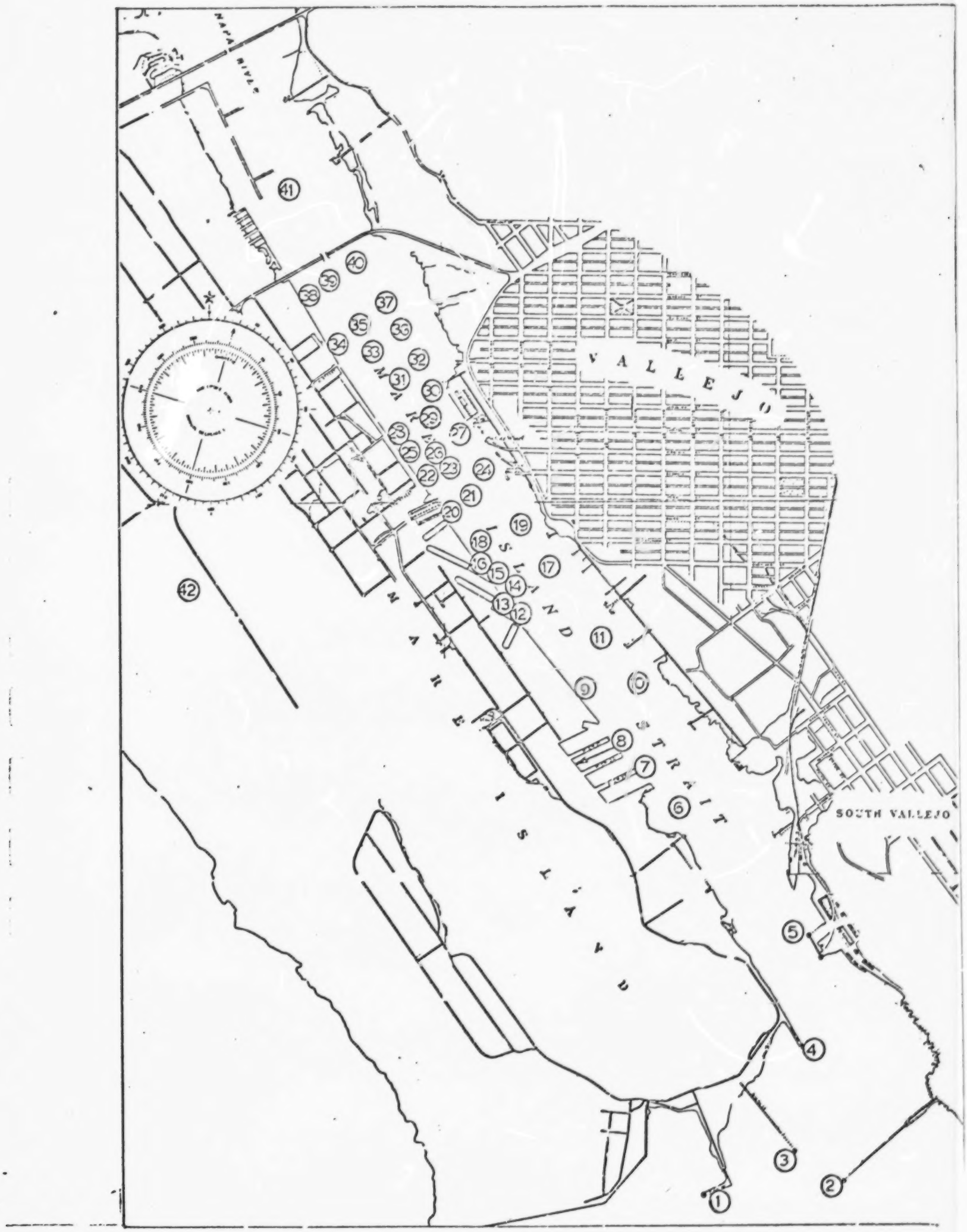


Figure 11. General Location of Sampling Points and Probe Readings at Vallejo

X. TABLES

SAN DIEGO

Location	Description	Laboratory Analysis Radionuclide* (pCi/gm ^{106}Ru	^{137}Cs	^{95}Zr	^{60}Co	Probe Estimate (pCi/gm) ^{60}Co	Estimate ($\mu Ci/M^2$) ^{60}Co	Sediment Sample Percent Moisture
1	Tip of Submarine pier	0.6			0.8	< 1.0	< 0.05	70
2	Middle of Submarine pier north side	0.6			1.6	< 1.0	< 0.05	46
3	Base of Submarine pier north side					< 1.0	< 0.05	
4	Bow of Sperry	0.4		0.7	7.1	25.0	(0.2)	60
5	Middle of Sperry	0.8		0.5	4.0	7.5	(0.10)	75
6	Stern of Sperry					< 1.0	< 0.05	
7	Off of Stern of Sperry				17.4	14.0	(0.4)	35
8	Midway between buoy "2" and Submarine pier					< 1.0	< 0.05	
9	Buoy "2"				0.5	< 1.0	< 0.05	39
10	Midway between Submarine pier and buoy "1"					17.0	0.4	
11	"L" Pier on Ballast Point	0.6			1.6	3.0	< 0.05	33
12	Tip on Ballast Point				0.2	< 1.0	< 0.05	30
13	Cove on north side of Ballast Point							
14	Buoy "RB" off Zuniga Point					< 1.0	< 0.05	
15	Shore line below Point Loma Coast Guard Station							
16	Dolphins off North Island opposite Ballast Point					< 1.0	< 0.05	
17	Pier on North Island southeast of bouy "14"					< 1.0	< 0.05	
18	Bouy "14"	0.6			2.5	< 1.0	0.6	36
19	Bouy "15"					< 1.0	< 0.05	
20	"L" Pier north of Submarine pier				5.8	1.5	0.15	48
21	Shore line at "L" pier							
[illegible]	North End-floating dry dock	0.8			1.7	2.0	< 0.05	52
	South end of fuel pier	0.6			1.5	2.3	< 0.05	52

Location	Description	Laboratory Analysis Radionuclide* (pCi/gm) ^{106}Ru	^{137}Cs	^{95}Zr	^{60}Co	Probe Estimate (pCi/gm) ^{60}Co	Estimate ($\mu Ci/M^2$) ^{60}Co	Sediment Sample Percent Moisture
24	North end of fuel pier				1.1	< 1.0	< 0.05	50
25	Tip of "F" pier	0.5			0.4	< 1.0	< 0.05	45
26	Buoy					2.3	0.06	
27	Shore line west side Shelter Island							
28	Buoy "16"					< 1.0	< 0.05	60
29	Fuel Pier on North Island across from Shelter Island					< 1.0	< 0.05	
30	Boat ramp on Shelter Island					< 1.0	< 0.05	
31	Buoy "18"					< 1.0	< 0.05	
32	Buoy "20"			0.7	1.8	1.0	0.05	66
33	Buoy "21"	0.8			2.1	< 1.0	0.05	65
34	Buoy "19"					< 1.0	< 0.05	

*Exclusive of natural activity.

Environmental Samples - San Diego

Location	Description	Sample	^{60}Co pCi/l or kg
12	Tip of Ballast Point	Harbor Water	NDA*
12	" " " "	Shore Sand	NDA
12	" " " "	Seaweed	
13	Cove at Ballast Point	Harbor Water	NDA
13	" " " "	Shore Sand	NDA
15	Point Loma	Ocean Water	NDA
15	Point Loma	Shore Sand	NDA
20	"L" pier north of Submarine Pier	Harbor Water	NDA
20	"	Shore Sand	NDA
27	Shelter Island	Harbor Water	NDA
27	" "	Shore Sand	NDA
27	" "	Fish (Needle Nose)	NDA
27	" "	Fish (Bonita)	NDA
17	Pier on North Island	Shore Sand	NDA
17	" " " "	Seaweed	
3	Base of Submarine Pier - Northside	Fish (Perch)	NDA
--	City of San Diego	Tap Water	NDA

* Exclusive of natural activity

VALLEJO

Location	Description	Laboratory Analysis Radionuclide* (pCi/gm)				Probe Estimate (pCi/gm)	Escimate ($\mu Ci/M^2$)	Sediment Samp: Percent Moisture
		^{106}Ru	^{137}Cs	^{95}Zr	^{60}Co	^{60}Co	^{60}Co	
1	Middle of Pier 35	2.9	0.6	1.0		< 1.0		73
2	Tip of Dike No. 9					< 1.0		
3	Tip of Dike No. 14	0.9	0.6	0.2		< 1.0		59
4	Tip of Pier 34					< 1.0		
5	Tip of General Mills Pier	1.9	0.6	0.7		< 1.0		66
6	Dolphin south of pier 23					< 1.0		
7	Tip of Pier 23	2.7	0.5	0.9		< 1.0		66
8	Base of Pier 21-22					< 1.0		
9	Berth 19					< 1.0		
10	East side of the Strait opposite berth 19					< 1.0		
11	East side of the Strait opposite berth 18					< 1.0		
12	Caisson at dry dock 4	3.0	0.5	1.0		< 1.0		74
13	Caisson dry dock 3	3.3	0.5	1.1		< 1.0		72
14	Mid-channel out of dry dock 3.					< 1.0		
15	1/4 of way out of dry dock 2	3.3	0.6	1.1		< 1.0		70
16	Caisson at dry dock 2	2.9	0.6	1.1		< 1.0		73
17	East side of Strait opposite dry dock 3					< 1.0		
18	Mid-channel out of dry dock 2					< 1.0		
19	East side of the Strait opposite dry dock					< 1.0		
20	Caisson at dry dock 1					< 1.0		
21	Mid-channel out of the ways					< 1.0		
22	Ferry landing	3.2	0.5	1.1		< 1.0		66
23	Mid-channel off ferry landing					< 1.0		
24	East side of Strait opposite ways	2.9	0.5	1.1		< 1.0		72
25	South end berth 9	3.4	0.5	1.0	0.4	< 1.0		74

Location	Description	Laboratory Analysis Radionuclide* (pCi/gm)				Probe Estimate (pCi/gm)	Estimate ($\mu Ci/M^2$)	Sediment Sample Percent Moisture
		^{106}Ru	^{137}Cs	^{95}Zr	^{60}Co	^{60}Co	^{60}Co	
26	Mid-channel berth 10					< 1.0		
27	East side opposite berth 10	2.3	0.4	0.8		< 1.0		69
28	North end berth 9	4.5	0.5	1.1		< 1.0		76
29	Mid-channel berth 9	3.3	0.5	1.0		< 1.0		70
30	East side of Strait opposite berth 9					< 1.0		
31	Mid-channel Berth 8	3.2	0.5	1.0		< 1.0		70
32	East side of Strait berth 8					< 1.0		
33	Mid-channel berth 7	1.8	0.7	0.5		< 1.0		70
34	Berth 6	2.7	0.5	0.9		< 1.0		65
35	Mid-channel berth 6					< 1.0		
36	East side of the Strait opposite berth 7	1.1	0.5	0.4		< 1.0		60
37	East side of the Strait opposite berth 6					< 1.0		
38	Berth 2					< 1.0		
39	Mid-channel berth 2	1.4	0.5	0.4		< 1.0		65
40	East side of Strait opposite berth 2	0.6	0.3	0.1		< 1.0		62
41	Reserve Fleet pier					< 1.0		
42	Dredge discharge line west side of Islan	0.6		0.1		< 1.0		35

* Exclusive of natural activity

Environmental Samples - Vallejo

Location	Description	Sample	^{60}Co pCi/l or kg
19	East Side of Stuart Opposite Dry Dock #2	Algae	NDA*
7	Tip of Pier 23	Fish	
28	North End Berth 9	Harbor Water	"
16	Caisson at Dry Dock #2	" "	"
24	East Side of Strait Opposite the Ways	" "	"
--	Mare Island Shipyard	Tap Water	"

* Exclusive of natural activity

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(1) Riel, G.K., New Underwater Gamma Spectrometer, Electronics, March 1963, pp 56-58.

(2) A Survey of San Diego Bay by United States Navy Volunteer Research Reserve Unit. 11-5, Progress Report No. 1, December 31, 1950.

(3) Personal communication from Mr. C. H. Tatum, U. S. Navy, San Francisco Bay Naval Shipyard, Vallejo, California, May 16, 1967.